The correlation of flower- and fruit-structure in Carica Papaya

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The papaya (*Carica Papaya* L.) is a small tree, — dioecious, or rarely bearing perfect flowers. The normal staminate flower is funnel-shaped with a long slender tube, the lobes being shorter than the tube and with ten anthers inserted in the throat of the corolla, the pistil being abortive. The normal pistillate flower is larger than the staminate and has distinct petals and a sessile ovary, which is large, round or angular, and contains numerous ovules. The stigma is sessile and five-rayed, with rays ultimately branched to six or more flattened lobes, and the stigmatic area extending a short distance around upon the dorsal surface (FIG. 1, *a*; for the sake of clearness only one of the five rays is shown).

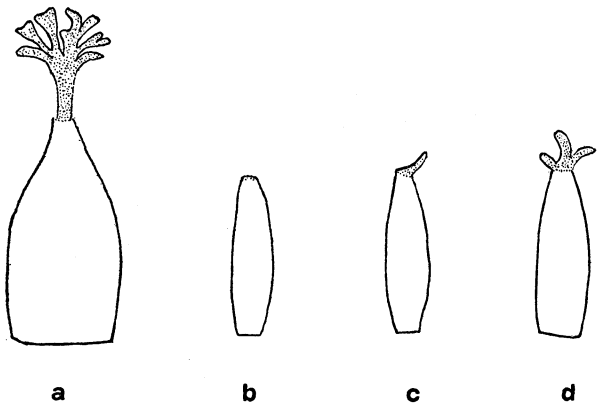

FIG. 1. Pistils of *Carica Papaya* showing different forms of stigma. (Enlarged about 1/5.)

During the summer of 1904 the attention of the writer was called to a rather unusual difference in the shape and size of the individual fruits on a papaya growing in the garden of the Subtropical Laboratory. The plant, being old, ceased to bear in the autumn and died later, but a cutting had fortunately been rooted successfully during the summer, and was planted out in the winter. Recalling the interesting fruits noted on the parent tree,

the development of this plant was watched with great interest. In July, 1905, the first flowers appeared. For several weeks all blossoms were staminate. In August several hermaphrodite flowers opened, which are rather rare in this species. By far the greater number of the flowers were staminate, but as the plant grew larger, quite a number of perfect flowers appeared in the axil of every leaf. On examination it was found that the structure of these flowers varied to a remarkable degree. Three distinct types of flowers were easily recognized: (1) those resembling a pistillate flower more than a staminate, large, tube one-half as long as lobes, anthers inserted in the throat of corolla, ovary large, angular, stigmatic end superior to anthers, ovules numerous, stigma normal; (2) those with the characters of both the staminate and pistillate flowers equally present, tube longer than in the type described above, ovary not so large, one or more of the stigmatic rays abortive, in some instances only a rudimentary ray being present (FIG. 1, *c* and *d*): (3) flowers approaching more closely a staminate flower in structure than either of the two classes mentioned, having the tube and lobes of equal length, ovary small, slender, ovules few, stigma reduced to a stigmatic area at the apex of the ovary (FIG. 1, *b*), inferior to or level with the anthers. It was noted also that the pollen masses were released just before or about when the flowers opened where it was inferior to or on a level with the anthers and in some instances, at least, where this organ was superior to the anthers.

In order to determine whether the development and formation of the fruit might be correlated with the structure of the flower, a series of notes was taken upon a number of flowers all on the same tree. In most instances the bisexual flower-buds were bagged with small paper sacks before they opened, the sack being retained until the flower had faded and the ovary was beginning to develop. Numerous small black ants frequent the flowers of the papaya to get the honey secreted, and to prevent a possible cross-pollination by these insects a broad band of cotton was tied around the trunk of the plant, which prevented their ascent. It may be mentioned here that bees or other large flying insects do not seem to act as fertilizing agents in this species, the pollen evidently being carried by the wind, or, more probably, by small insects, from the stami-

nate flowers to the pistillate. All the male flower-buds on the plant were picked before they opened to prevent a possible conveyance of pollen from them by the wind to the flowers not bagged. Twenty-three flowers were numbered as they opened and the differences in their structure noted. Seven of these were not bagged. Of the flowers that did not set fruit, two had small ovaries with stigma reduced to a stigmatic area at the apex of the ovary, one of these two not being bagged. Five fruits were injured by insects so that they dropped or ripened prematurely and one was cut to give the other fruits more room. The first fruit was picked April 23, 1906, and the last June 26. As they were tested each fruit was weighed then cut through the center longitudinally with a sharp knife and an outline of the fruit and cavity traced on a paper. The dried seed from each fruit was also weighed. That the hermaphrodite flowers do not need external aid in pollination and that they are fertile with their own pollen was fully demonstrated, as in no instance were the flowers hand-pollinated. The chances that the unbagged flowers were fertilized by the wind were also exceedingly slight, as no male plants were growing in the vicinity. The supposition that the characters of the flower might be correlated with the form and size of the fruit was fully borne out and is best illustrated in the accompanying photograph (FIG. 2) of the tracings of six fruits. By referring to the following notes corresponding to the numbers above the outlined fruits it will be seen that where the ovary was small and slender, with rays in the stigma nearly aborted, the fruits grew comparatively small, cylindrical and oblong, almost solid, with exceedingly small seed-cavity containing few seeds, while where the pistil was normal, or nearly so, the fruits grew large, more or less angular, with the apical end distended, and the cavity containing a large number of seeds.

Unfortunately, no fruits matured from flowers where the stigma was rayless, as the fruits dropped, being injured by insects. The following notes all refer to hermaphrodite flowers:

No. 2. October 5, 1905. Flower bagged; tube long; ovary slender; stigma reduced to stigmatic area at apex of ovary with one short ray like FIGURE 1, *c*; mature April 23; weight of fruit 600 grams; seed-cavity small; weight of dried seeds 2 grams. (FIGURE 2, no. 2.)

No. 4. October 7, 1905. Flower not bagged; tube long; ovary slender; stigma reduced to stigmatic area at apex of ovary with short ray like FIGURE 1, *c*; mature April 23; weight of fruit 345 grams; seed-cavity very small, containing few seeds; weight of dried seed one gram. (FIGURE 2, no. 4.)

No. 7. October 10, 1905. Flower bagged; tube long; ovary slender; stigma reduced to stigmatic area at apex of ovary with three short rays, about like FIGURE 1, *d*; fruit mature April 23; weight of fruit 520 grams; seed-cavity small, containing few seeds; weight of dried seed 2 grams. (FIGURE 2, no. 7.)

No. 15. October 17, 1905. Flower bagged; tube short; ovary large and angular; stigma normal like FIGURE 1, *a*; fruit mature May 8; weight of fruit 2115 grams; seeds numerous and more than lining cavity; weight of dry seed 15 grams. (FIGURE 2, no. 15.)

No. 16. October 18, 1905. Flower bagged; tube short; ovary very large and angular; stigma normal like FIGURE 1, *a*; fruit mature May 31; weight of fruit 1620 grams; cavity well filled with seed; weight of dried seed 15 grams. (FIGURE 2, no. 16.)

No. 17. October 18, 1905. Flower bagged; tube short; ovary very large and angular; stigma 4-rayed, otherwise normal; fruit mature June 6; weight of fruit 1920 grams; weight of dried seed 16 grams. (FIGURE 2, no. 17.)

The fruits developed from flowers in which the stigmatic rays were almost entirely abortive contained several undeveloped ovules, and the fruits were smaller than those developed from flowers where the stigmatic area was large. No. 14, flower bagged, was an interesting exception. The flower to this fruit was similar to that of no. 15. On maturity the fruit weighed 580 grams. Of a large number of ovules very few had developed to seed, which, dried, weighed only 0.75 gram. The general outline of the fruit was similar to that of no. 15 and the seed-cavity was proportionately as large. It is possible that the inferior size of this fruit may have been due to imperfect pollination, so many ovules having failed to develop, and it may partly be the cause of the small size of nos. 2, 4, and 7 also, although it is believed that a difference in the structure of the pistil is the greatest factor in determin-

ing the growth and development of the fruits, in view of the fact that the number of ovules is small and the wall of the ovary thick where the stigma is small, while the number of ovules is great and the cavity large and the ovary wall thin where the stigmatic area is large.

The seed from the different fruits was saved and planted in 1906. A large number of these seedlings perished, unfortunately, in the hurricane in October and the severe freeze of December the same year. Of those that survived a very much larger number proved to be hermaphrodite plants than is the case with seedlings grown from fruits commonly found in the market.

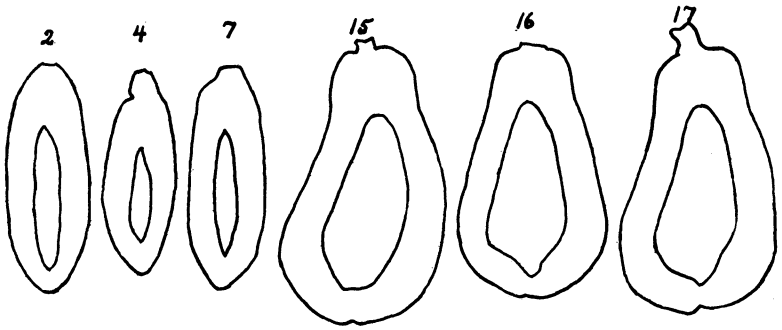

FIG. 2. Outlines of fruits of *Carica Papaya*. (About 1/6 natural size.)

Since the above notes were made, the flowers on a large number of papaya plants have been examined. Few hermaphrodite plants are found, but, in all trees bearing bisexual flowers that have been noted, the variation in the structure of the flowers, as stated above, has been recorded.

The papaya, as commonly propagated at present, has too large a percentage of worthless seedlings to be commercially profitable. Good material for cuttings is, from the nature of the tree, difficult to obtain and is so difficult to root without bottom heat — seldom or never used in rooting plants in the tropics or subtropics — that this mode of propagating a good variety does not commend itself. It has been demonstrated at the Subtropical Laboratory that inarching can be done, but this is necessarily a slow and cumbersome method of propagation.

An attempt to originate a variety of papaya by inbreeding

would probably be more successful if the flowers were hand-pollinated with their own pollen than if pollination were accomplished with pollen from flowers differing in structure. It seems quite probable that in a batch of seedlings grown from an individual fruit with small seed-cavity and few seeds — the flowers of course being bisexual — some seedlings would have a greater percentage of flowers that would develop this type of fruit, which would be preferable commercially to fruits with large cavities containing numerous seeds. It is probable that by inbreeding and rigid selection for several generations a variety of papaya bearing all its fruits of this type might be originated, which, the flowers being self-pollinated, would reproduce itself true to the variety.

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